Make your system firmware faster, more flexible and reliable with LinuxBoot

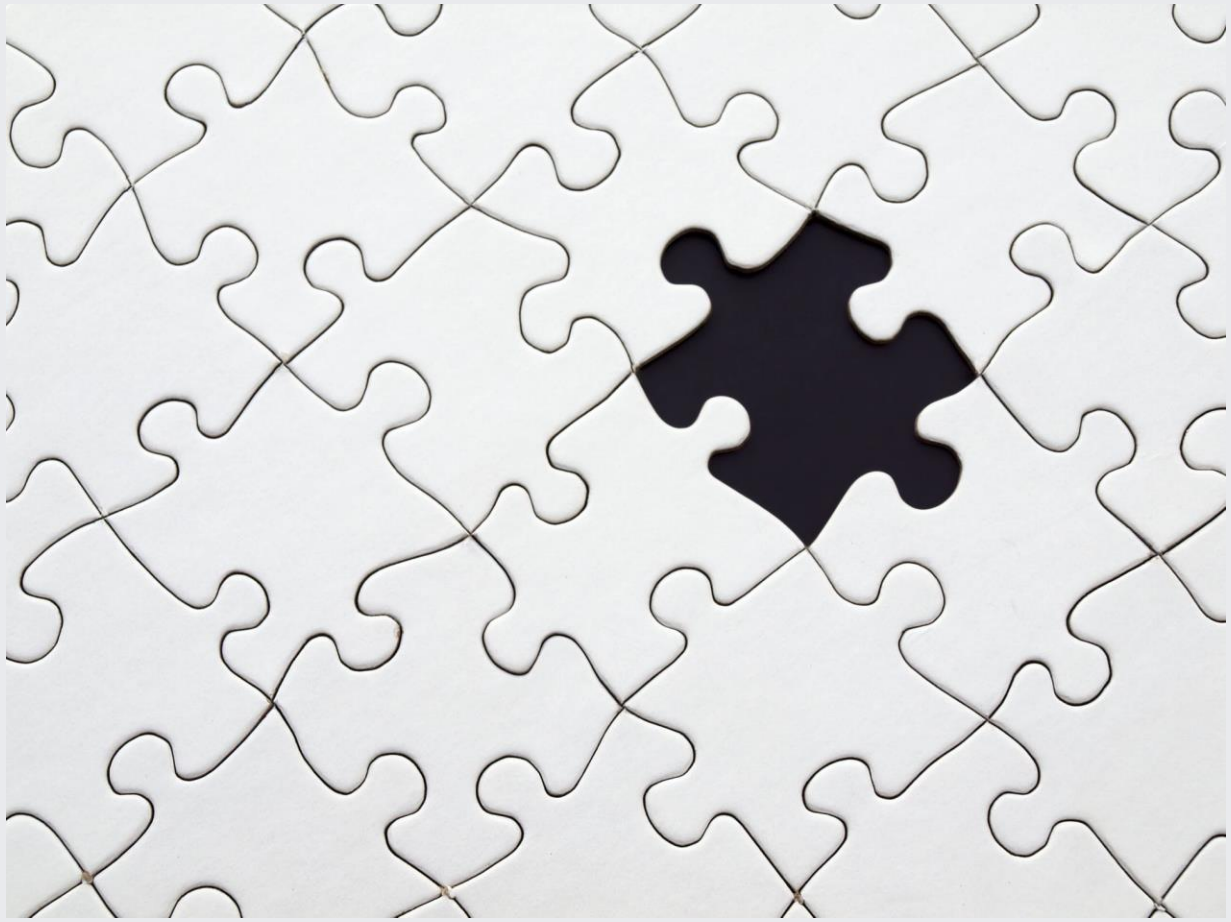
David Hendricks: Firmware Engineer
Andrea Barberio: Production Engineer

Open Source @ Facebook

- Facebook promotes open source
  - Systems Software: Kernel, CentOS, chef, systemd, etc.
  - Hardware: Open Compute Project, Telecom Infrastructure Project
  - Lots more: https://github.com/facebook and https://github.com/facebookincubator

...but there is a missing piece

Any guesses?



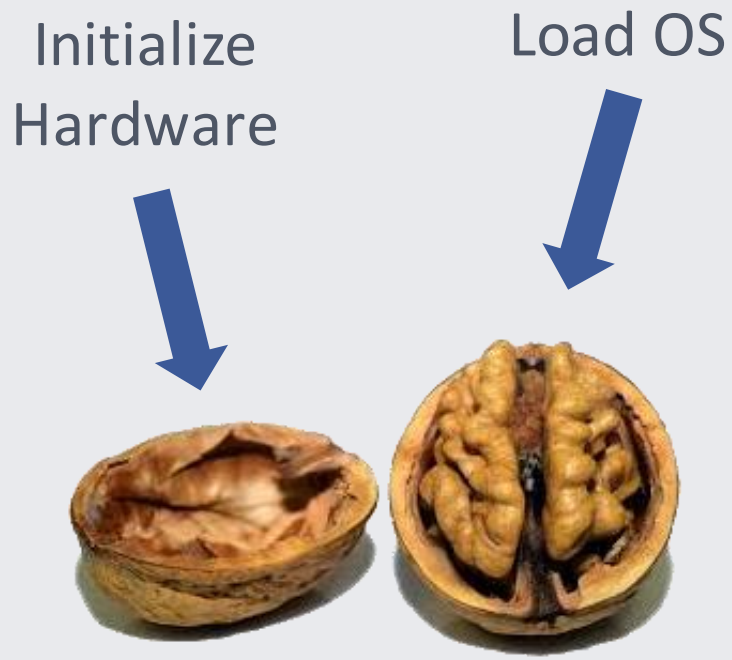
Open Source Firmware @ Facebook

OpenBMC initially released in 2015 and is quickly becoming standard on OCP hardware

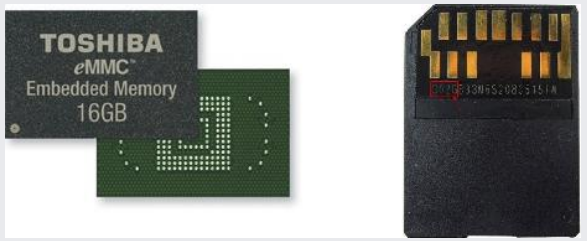
System firmware is the next logical step

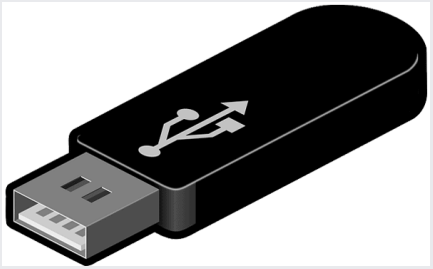
System firmware in a nutshell

- First bit of code that runs when CPU is turned on
- Sometimes referred to as "BIOS"



Problem: Local booting is more complex





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Few, simple interfaces	Many interfaces and protocols

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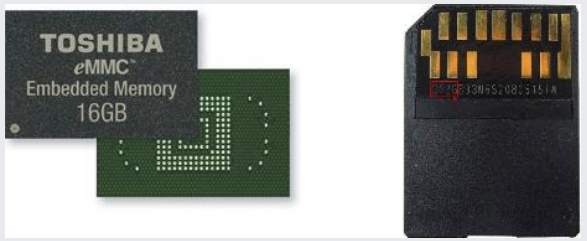

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Simple, low-speed links	High-speed links

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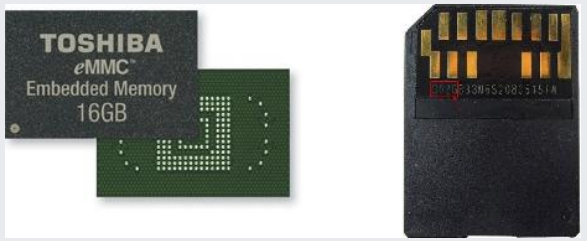

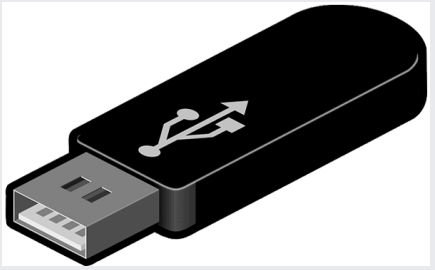

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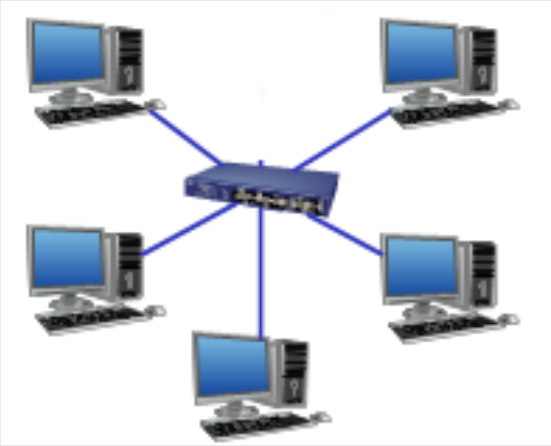
Simple, low-speed links	High-speed links
Blindly execute MBR (CHS 0/0/1)	Decrypt & mount filesystem

Problem: Network booting is more complex



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Small, trusted networks	Global, untrusted networks

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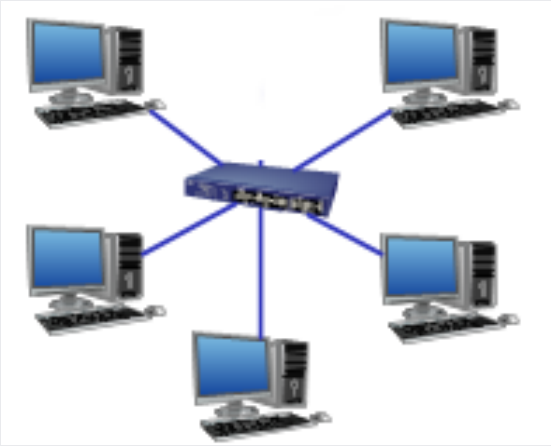

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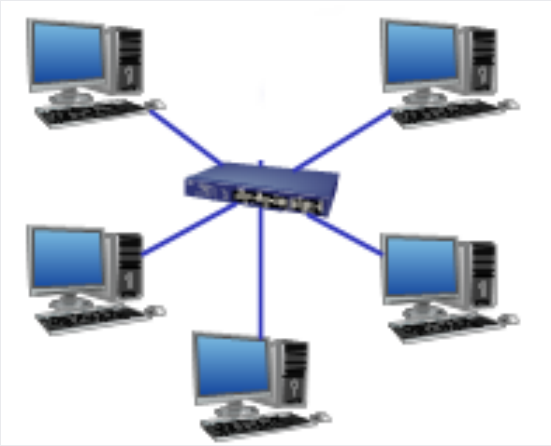

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Small, trusted networks	Global, untrusted networks
Few, simple interfaces and protocols	Many interfaces and protocols
TFTP/PXE, security an afterthought	TLS/HTTPS, designed for security

TL;DR: SysFW is complex

Then/Now
SysFW/BIOS contains an OS

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Vendor-specific tooling
Product-specific

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LinuxBoot

Then/Now	Now/Future
SysFW/BIOS is an OS	Let Linux Do It
Opaque	
Proprietary ecosystem	
Vendor-specific tooling	
Product-specific	

The Solution: Let Linux Do It

LinuxBoot

Then/Now	Now/Future
SysFW/BIOS is an OS	Let Linux Do It
Opaque	Open, well-understood at FB
Proprietary ecosystem	Auditable, debuggable
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Then/Now	Now/Future
SysFW/BIOS is an OS	Let Linux Do It
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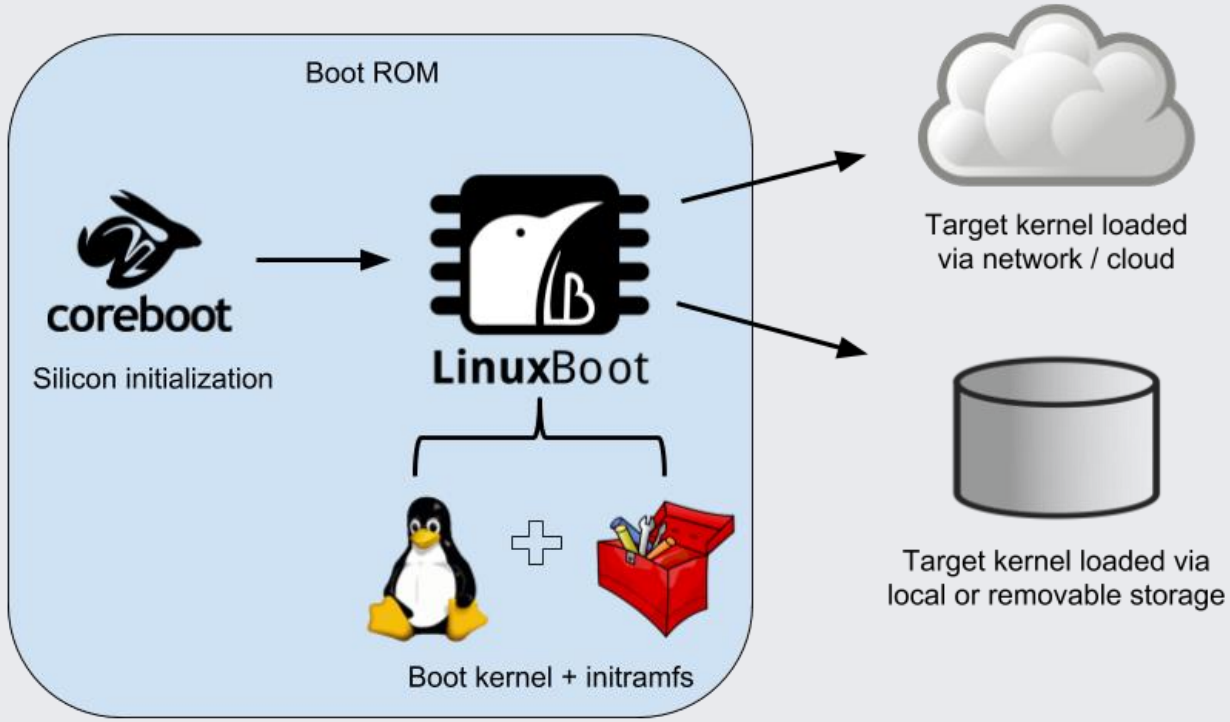
Proprietary ecosystem	Auditable, debuggable
Vendor-specific tooling	Open-source tools
Product-specific	Portable, re-usable

Let Linux Do it

- Put a kernel+initramfs in boot ROM
- Do minimal silicon init and jump to Linux as soon as possible
- Use Linux to boot Linux



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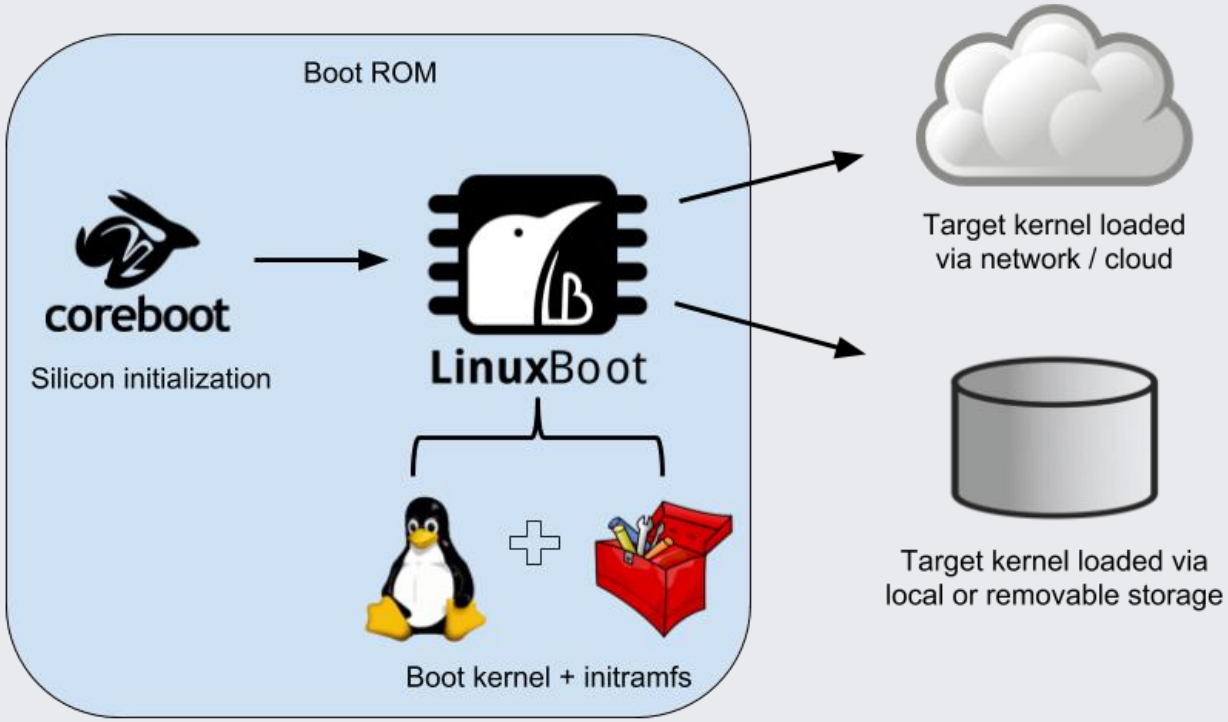
- **Production-quality drivers, networking**
- **Add features + tools as needed**
- **Debug, build, deploy on our schedule**



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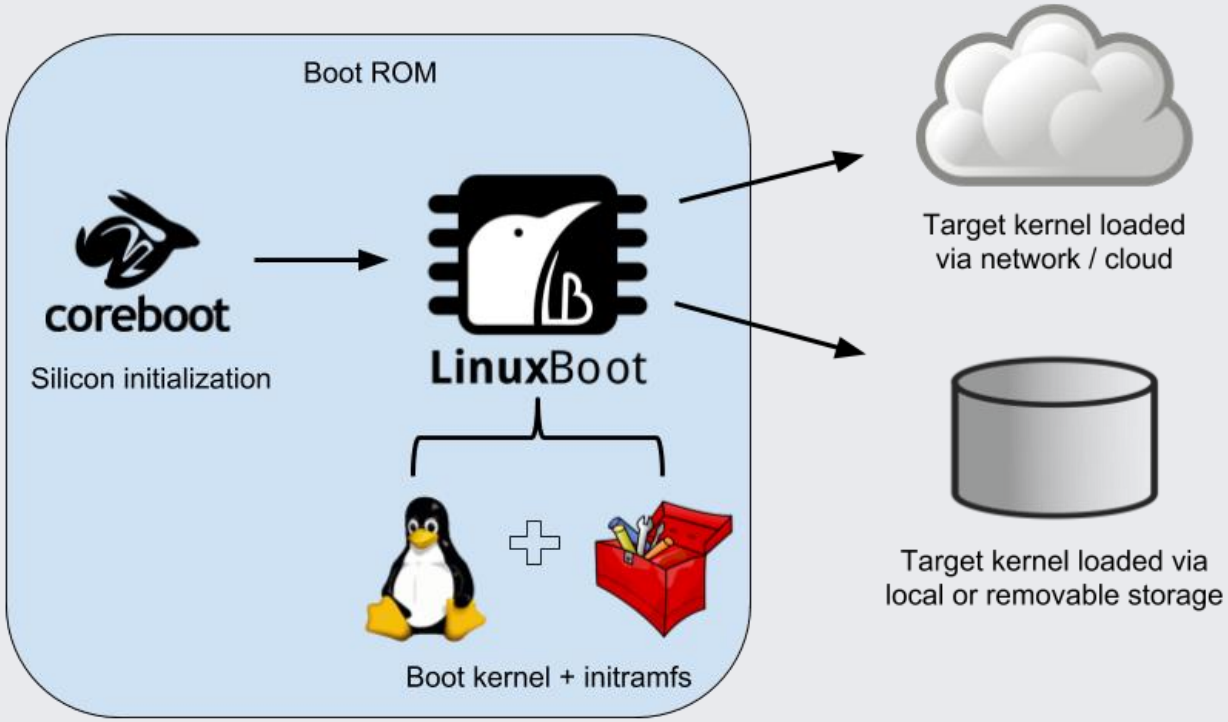
- **Flexible security architecture**
- **Boot in seconds, not minutes**
- **Bring modern, open-source development to the firmware**



Why open source firmware?

Open Source Firmware @ Facebook

Scoping out the problem

That's a lot of servers

(and switches, too!)

...and we're not just working on datacenters.

OS provisioning

OS Provisioning

- Andrea Barberio – Host Provisioning Engineering @ Facebook

- Installing an OS on a single machine is simple
- Installing an OS at scale is complex
  - Lots of moving parts
  - Network booting introduces noise

Provisioning a physical machine

- From the machine's perspective:
  - Power on
  - DHCPv6 (firmware)
  - TFTP (firmware)
  - installer starts

Boot process issues

- It works most of the times
- However:
  - DHCP and TFTP implementations can have bugs
  - Different firmwares can have different bugs
  - Fixing one firmware doesn't fix the others
- At scale, a small fraction of errors can translate to a lot of operations

LinuxBoot in provisioning

- LinuxBoot can simplify provisioning a lot
  - Tested DHCP/TFTP implementations
  - Better protocols: HTTPS instead of TFTP
  - Consistent firmwares everywhere
  - We know and control what that we run

Firmware testing and upgrades

- Testing and upgrading firmware now depends on vendors
  - Different vendors have different standards and response time
  - Vendors may be unable to reproduce the issue on their infra
- On our side:
  - Debugging closed source firmware can be hard
  - Once the update is ready, we run our validation
- Rinse and repeat

- The time between bug identification and roll-out to prod can be very long
- We want to speed this process up, and enable in-house debugging
- LinuxBoot allows us to do this

Not just firmware: LinuxBoot as OS installer

- LinuxBoot is not just for firmwares
- Its components can be successfully used as a bootloader or an OS installer
  - We want to boot the infra with the same code that provisions our infra
- Facebook is experimenting systemboot as:
  - Local bootloader and installer: ProvLauncher
  - Network installer: YARD

LinuxBoot architecture @ FB

Architecture

coreboot, LinuxBoot, u-root, systemboot?

Multiple open-source components:

- **coreboot**: low-level hardware initialization
- **Linux**: device drivers, network stack, multiuser/multitask environment, etc
- **u-root**: user-space environment with command-line utilities
- **systemboot**: additional tools, and bootloader "personality"

u-root

User-space initramfs written in Go

Think of it like busybox, but written in Go

- Multi-architecture
- Single binary, all the tools built-in, symlink determines what to run
- Alternatively, source mode: modify and recompile on the fly
- Fast build time: <10s on a modern laptop
- Created at Google; contributors from Facebook, 9elements, and several others

systemboot

A bootloader distribution based on u-root

- systemboot is a "distro" that implements a bootloader
  - Based on u-root, also written in Go

We want components that provide flexibility in various boot scenarios, and that we can iterate fast on

systemboot workflow

- Look for boot entries in VPD vars: *Boot0000*, *Boot0001*, ...
- Find a *Booter* for the boot entry, and try it
- If it fails, try the next boot entry, until one succeeds
- If all fails, start over

Boot entries

- Boot entries and their order are stored in VPD variables
- Value in JSON format. Example:

- **Boot0000**={
  "type":"netboot",
  "method":"dhcpv6",
  "mac":"00:fa:ce:b0:0c:00"
  }

- **Boot0002**={
  "type": "localboot",
  "kernel": "/path/to/kernel",
  "device_guid": "….",
  }

Building systemboot

- Use the **u-root** ramfs builder and a valid kernel:

```
go get –u github.com/u-root/u-root
go get –u github.com/systemboot/systemboot/{uinit,localboot,netboot}
"${GOPATH}/bin/u-root –build=bb core \
    github.com/systemboot/systemboot/{uinit,localboot,netboot}
```

- Try it!

```
qemu-system-x86_64 -nographic -kernel /path/to/your/kernel \
    -initramfs /tmp/initramfs.linux_arm64.cpio
```

Booter interface

Can be used to

- Implement new boot methods
  - e.g. “brute-force” bootloader
- Define new boot policies
  - e.g. fail if signature is bad; or continue and leave it to remote attestation
- Implementation:
  - Define JSON structure and custom *Boot()* method

Example: netbooter

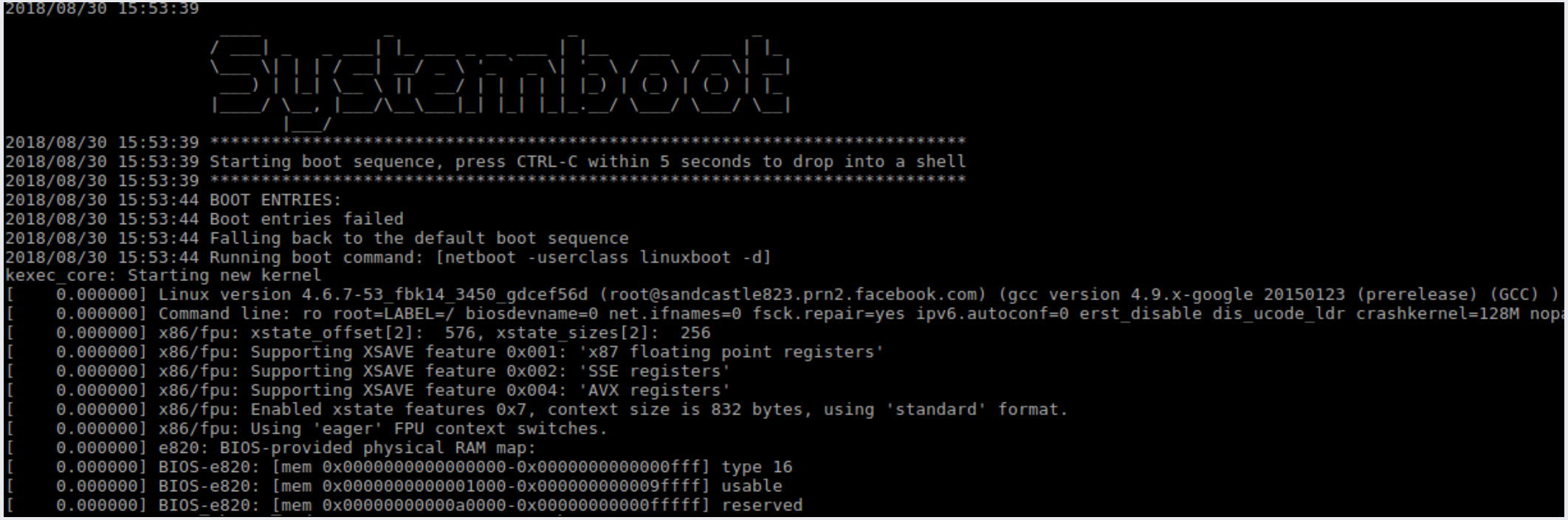
https://github.com/systemboot/systemboot/blob/master/pkg/booter/netbooter.go

```
type NetBooter struct {
    Type string `json:"type"`
    Method string `json:"method"`
    MAC string `json:"mac"`
    OverrideURL string `json:"override_url,omitempty"`
}
```

Example: netbooter

```
func (nb *NetBooter) Boot() error {
    bootcmd := []string{"netboot", "-d", "-userclass", "linuxboot"}
    cmd := exec.Command(bootcmd[0], bootcmd[1:]...)
    cmd.Stdin, cmd.Stdout, cmd.Stderr = os.Stdin, os.Stdout, os.Stderr
    if err := cmd.Run(); err != nil {
        return fmt.Errorf("Error executing %v: %v", cmd, err)
    }
    return nil
}
```

Systemboot demo



Thanks!

Questions?

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Andrea Barberio <barberio@fb.com>

Additional resources:

- linuxboot.org
- u-root.tk
- systemboot.org
- tpmtool.org
- opencompute.org
- telecominfraproject.com